Space Weather Technical Forecast

Issued on Thursday, 28 December 2023 at 13:18 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Risk of G1/Minor Storm or perhaps G2/Moderate Storm from CMEs on day 1 (28 Dec). Slight chance of R1/Minor Radio Blackouts. Slight chance of Active fluence later in the period.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the past 24 hours, with only minor C-class flares observed. There are currently seven sunspot regions on the visible disc. AR3534 near the southeast limb has a faint delta portion in its intermediate spot. AR3533 in the northwest continues to develop, with intermediate spots now evident. AR3529 in the southwest is the largest region but remains inactive. AR3531 is a unipolar region with two spots. The other regions are currently smaller and simpler. No new Earth-directed Coronal Mass Ejections (CMEs) were seen in imagery, although numerous potential sources remain in the form of many filaments on the disc.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR at L1, were slightly elevated throughout the period. Wind speeds varied between 420-480 km/s. The density was mostly average. The IMF was weak at 7nT or lower, while the north-south component was mostly positive and weak. The phi angle was positive (away from the Sun). Geomagnetic activity was Quiet (Kp 0-1) through the period.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was occasionally very slightly raised above normal background levels, although well below the S1/Minor Storm threshold.

GOES16 high energy (greater than 2MeV) electron flux was at mostly moderate levels. The 24-hour fluence was below Active throughout on a very slight rising trend. The 28/0000 UTC observation was 9.42e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low activity is likely to continue, with a slight chance of isolated M-class X-ray flares.

Solar Wind / Geomagnetic Activity: Two potential CME arrivals are expected on day 1 (28 Dec), but with great uncertainty in timing due to their potential interaction. Solar wind speeds will likely return to background levels later day 2 or day 3. Coronal hole 86 may give a high speed stream later on day 4 (31 Dec), with speeds reaching Elevated or Strong.

Geomagnetic activity will probably be Quiet at first, though an increase is likely in the event of one or more CME arrivals. This is likely to give an increase to Active to G1/Minor Storm conditions on day 1, with a chance of G2/Moderate Storm intervals. Activity should slowly tail off through day 2 (29 Dec), becoming largely Quiet on day 3 (30 Dec). Unsettled to Active conditions are then possible later on day 4 should we see the high speed stream arrive.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is near background and likely to persist at this level, but with a very slight chance of reaching S1 given any further notable flares from AR3529 or other regions on the disc.

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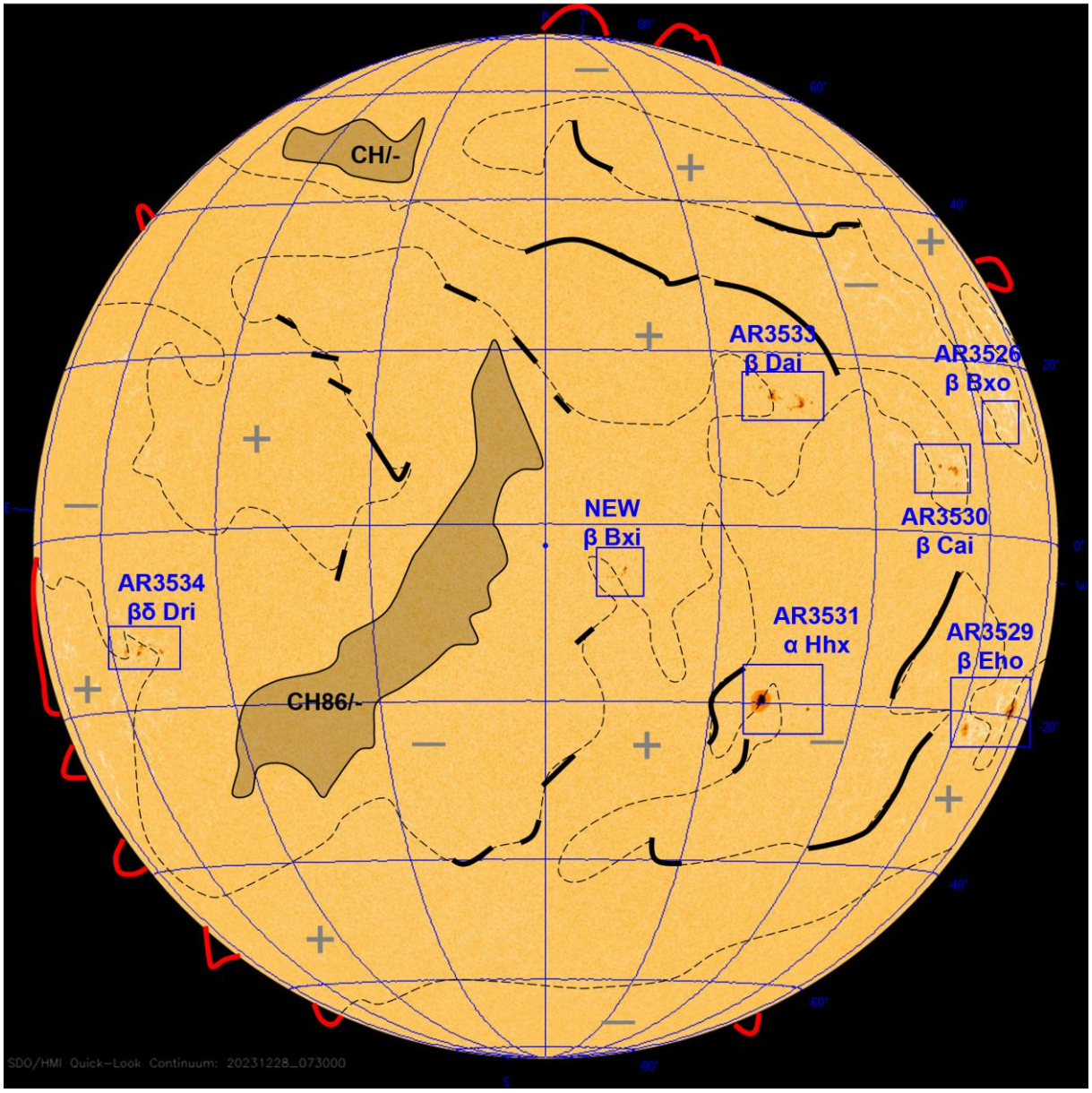
Met Office Space Weather Technical Forecast

GOES16 high energy electron flux is likely to be suppressed in the near term with CME arrivals, but may rise days 3 and 4 (30-31 Dec), with a slight chance of reaching Active levels.

Figure 1. Solar Analysis Valid *.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A great number of CMEs were observed over the Christmas period, three were deemed to perhaps have an earth directed element, though the first is now assessed to have missed. Two further CMEs may arrive during 28 Dec, though the forecast carries high uncertainty given the marginal effects from each CME, but also due to their probable inter-connectivity, with one possibly priming the interplanetary medium for the next.

The first was a coronal dimming from the southwest disc, around 24/1430UTC. This may deliver a glancing blow early in the period. This CME is angled mainly below and ahead of the Sun-Earth line.

The final, and most directly, a coronal dimming that occurred just northeast of centre-disc around 25/0700UTC. This presented on coronagraph imagery as a halo with a slight eastward bias. This will likely affect Earth, however the main uncertainty here is the arrival time - given the poor triangulation offered by STEREO and Lasco viewpoints at this point in time, but also because the earlier glancing CMEs may impede or sweep clear the interplanetary medium ahead of this following halo.

MOSWOC Enlil Ensemble shows the large amount of uncertainty and possibility of either separate arrivals or a very large united density front. At least half of the ensemble members showed some enhancement before now. The wind speed in the model is currently just a little slow compared to the actual wind speed.

Finally, coronal hole 86 may give a high speed stream later on day 4 (31 Dec). This is a persistent feature which arrived on the equivalent of late day 3 (30 Dec) on the previous rotation. However, on this pass it appears slightly smaller with the leading edge further back than last time around, hence the later arrival estimate. At this time of year we are near the biannual minimum in geomagnetic response to coronal hole high speed streams, so geomagnetic effects from this feature are likely to be muted.

Geomagnetic activity will probably be Quiet at first though an increase is likely in the event of one or more CME arrivals as discussed above, but with large uncertainty in timings. This is likely to give an increase to Active to G1/Minor Storm conditions on day 1 (28 Dec), with a chance of G2/Moderate Storm intervals. Activity should slowly tail off through day 2 (29 Dec), becoming largely Quiet on day 3. Unsettled to Active conditions are then possible later on day 4 should we see the high speed stream arrive.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	60	20	1	10
Strong	G3	No	5	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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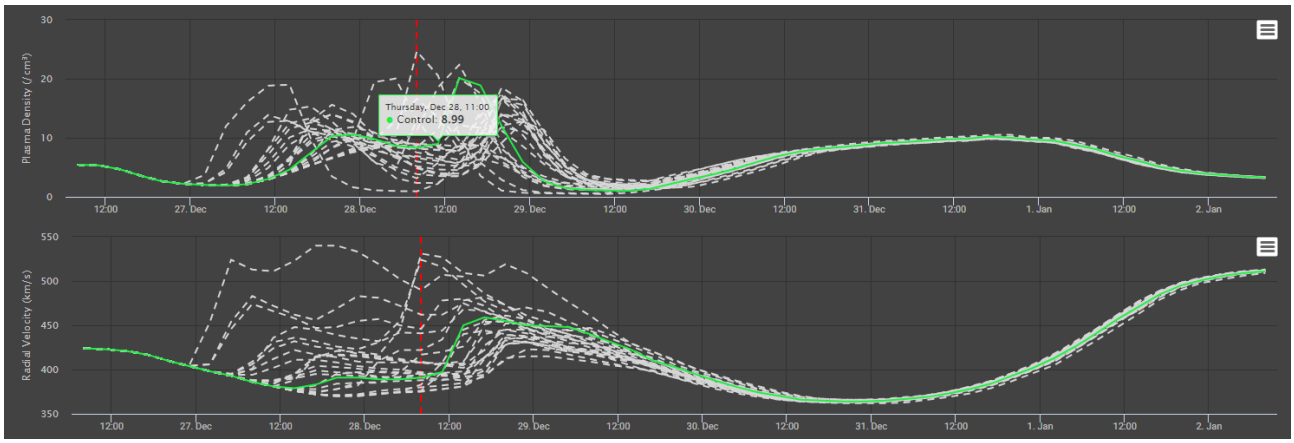
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/2224	Partial	Filament	SW	572 km/s	28/0600 UTC +/- 12 hours	Low confidence glancing blow
25/1442	Full	Filament	NE centre	538 km/s	28/1400 UTC +/- 12 hours	High confidence hit, low confidence in timing

Figure 2: MOSWOC ENLIL Ensemble



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Radio Blackouts - X-Ray Flares:

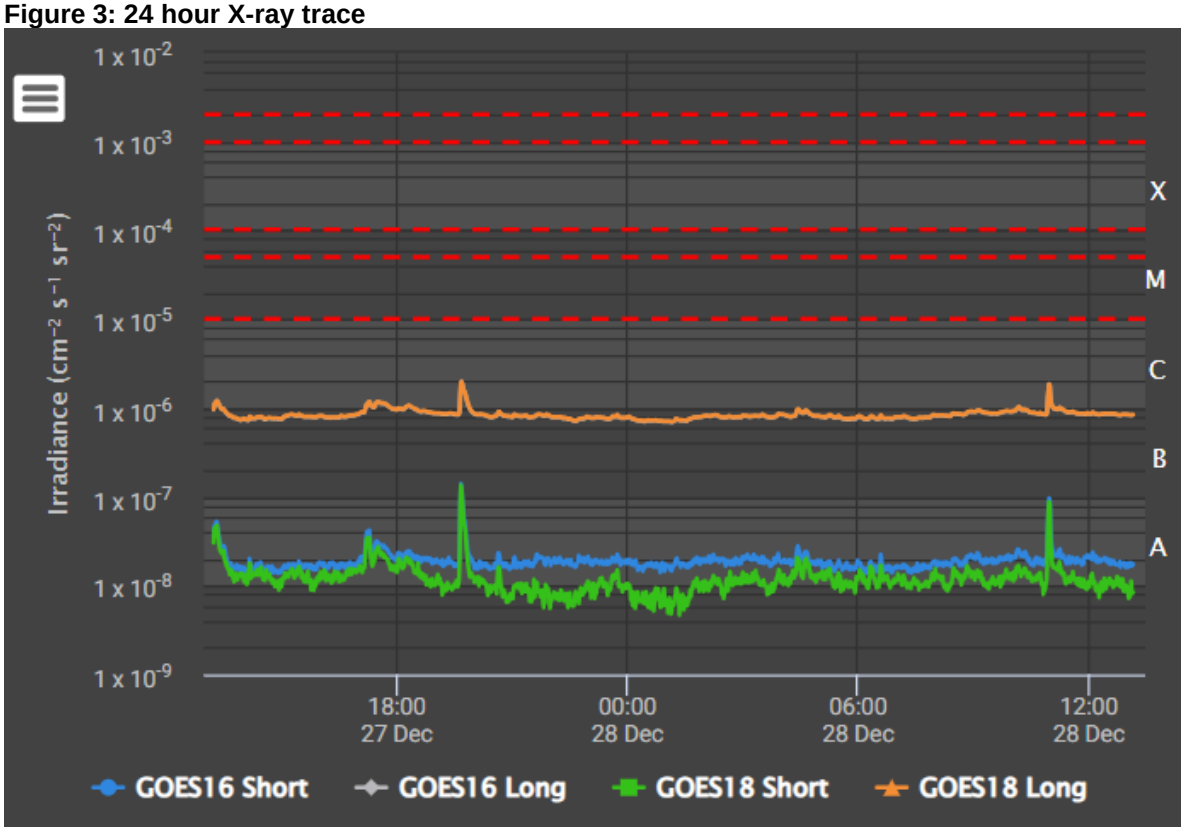
Solar activity is likely to be Low, with a slight chance of Moderate activity.

There have only been isolated minor C-class flares in the last 24 hours. Most of the sunspot regions on the facing side show relatively little magnetic complexity at present, although AR3534 near the southeast limb is showing tenuous signs of a delta magnetic configuration. There are currently seven sunspot regions on the visible disc. AR3533 in the northwest continues to develop, with intermediate spots now evident. AR3529 in the southwest is the largest region but remains inactive. AR3531 is a unipolar region with two spots. The other regions are currently smaller and simpler.

Far side seismographs do not suggest any significant regions just over the east limb at the present time, so flare probabilities have been reduced a little as AR3529 rotates off the disc early on Day 3 (30 Dec).

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	20	20	20	15
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 3: 24 hour X-ray trace



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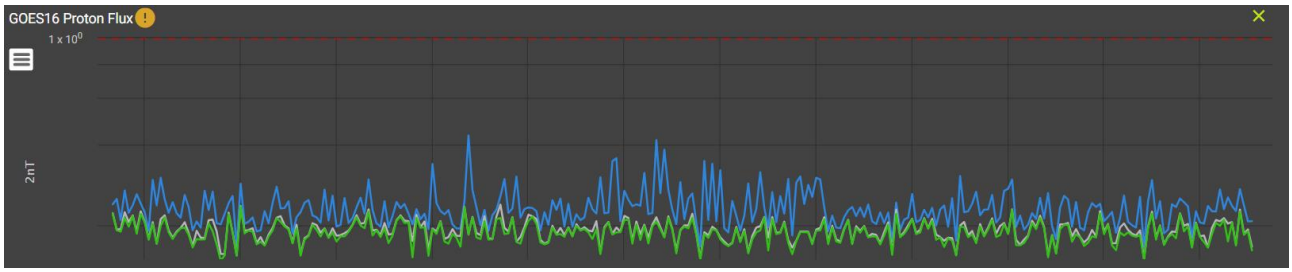
Solar Radiation Storms - (High Energy Protons):

GOES16 high energy (greater than 10MeV) proton flux was occasionally very slightly raised above normal background levels in the last 24 hours, although well below S1/Minor Storm levels (10pfu). The cause of this is not known, however given the very gradual rise and soft spectrum, it may be a far side or even eastern limb event, perhaps even the long-period M1.1 from behind the eastern horizon on 24 December. It does appear to be trending towards normal background once again.

There is a very slight chance of proton enhancement if any further M-class flare activity were to occur.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: 24 hour Proton trace



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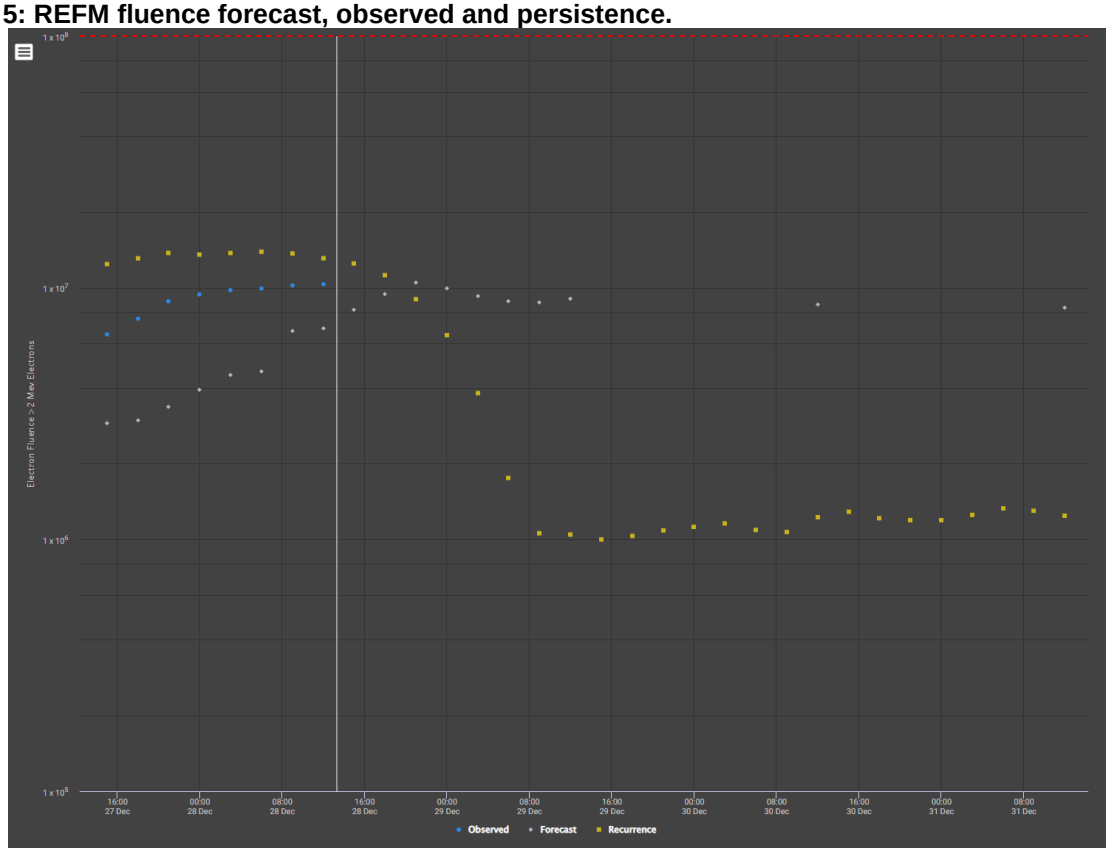
High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES16 has been largely at moderate levels. With one or more CME impacts possible on Day 1 (28 Dec), and with effects likely continuing into Day 2 (29 Dec), flux at GEO is likely to remain suppressed in the short term. Some increase is possible on Day 3 into 4 (30-31 Dec) after the CME effects have waned, but a potential high speed stream arrival later Day 4 will probably suppress flux levels once again.

The associated 24-hour fluence is expected to persist below Active (1e8 integrated pfu) for the next couple of days, perhaps rising on Days 3 and 4, before a potential suppression later on Day 4. Once we see the level of geomagnetic activity from any CME effects by the end of Day 1 (28 Dec), we will have a better idea of the likelihood of a fluence increase later in the period. MOSWOC REFM will not be taking into account the possibility of CME arrival(s) in the short term, so although the below Active forecast is likely correct at first, it won't be able to forecast any potential increase later in the period until after the CME(s) have arrived.

GEO Electron Environment	Level ($cm^{-2}\ sr^{-1}\ day^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	10	20
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: REFM fluence forecast, observed and persistence.



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